

RECOVERY PLAN FOR MARSILEA VILLOSA

APRIL, 1996



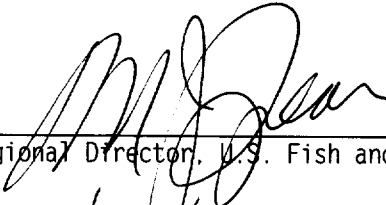
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Recovery Plan
for
Marsilea villosa

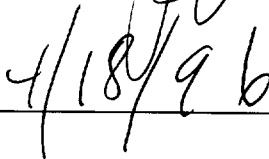
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Approved: _____

 Michael J. Spear
Regional Director, U.S. Fish and Wildlife Service

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THIS IS THE COMPLETED RECOVERY PLAN FOR MARSILEA VILLOSA. IT DELINEATES REASONABLE ACTIONS THAT ARE BELIEVED TO BE REQUIRED TO RECOVER AND/OR PROTECT THE SPECIES. OBJECTIVES WILL BE ATTAINED AND ANY NECESSARY FUNDS MADE AVAILABLE SUBJECT TO BUDGETARY AND OTHER CONSTRAINTS AFFECTING THE PARTIES INVOLVED, AS WELL AS THE NEED TO ADDRESS OTHER PRIORITIES. THIS RECOVERY PLAN DOES NOT NECESSARILY REPRESENT OFFICIAL POSITIONS OR APPROVALS OF THE COOPERATING AGENCIES, AND IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF ALL INDIVIDUALS WHO PLAYED A ROLE IN PREPARING THE PLAN. IT IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS, CHANGES IN SPECIES STATUS, AND COMPLETION OF TASKS DESCRIBED IN THE PLAN.

Literature citation:

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ACKNOWLEDGEMENTS

This recovery plan for Marsilea villosa was prepared by Ms. Marie M. Bruegmann, during her employment with the Center for Plant Conservation, St. Louis, Missouri. Ms. Bruegmann currently works for the U.S. Fish and Wildlife Service, Ecological Services, Pacific Islands Office, in Honolulu, Hawaii. Modifications to this plan have been made by the U.S. Fish and Wildlife Service.

EXECUTIVE SUMMARY

Current Species Status: Marsilea villosa is a fern endemic to the Hawaiian Islands. There have been eleven populations reported on three islands, six of which are assumed to be extirpated. The extant populations are found on O`ahu and Moloka`i. The species was listed as endangered by the U.S. Fish and Wildlife Service on June 22, 1992. Four of the remaining populations are naturally occurring; a fifth population has been planted. The total number of extant individuals is unknown due to the clonal nature of the species, but total area covered is 6-10 acres.

Habitat Requirements and Limiting Factors: Marsilea villosa is found in areas that flood periodically, such as small depressions and flood plains with clay soils. Standing water is required for sexual reproduction, and drying is required for new plant establishment and for sporocarp maturation. Shading reduces vigor of Marsilea villosa. Limiting factors include competition from invasive alien plant species, development, narrow habitat requirements, small population sizes, fire, habitat degradation by off-road vehicles, and trampling and other impacts by humans and introduced mammals.

Recovery Objective: To delist Marsilea villosa.

Recovery Criteria: Marsilea villosa will be considered for downlisting when six geographically distinct, self-sustaining populations (three on O`ahu and three on Moloka`i or three on O`ahu, two on Moloka`i, and one on Ni`ihau) are adequately protected and have been maintained through two successive floods resulting in sexual reproduction. The number of individuals per population cannot be designated due to the clonal nature of the species. The year of downlisting is dependent on rainfall, and cannot be predicted at this time. A population will be considered to be self-sustaining when it is observed to be successfully reproducing and the population size is increasing.

Marsilea villosa will be considered for delisting when active management is no longer needed to maintain the downlisting criteria for six populations. More detailed criteria for delisting Marsilea villosa will be established when more is known about the biology and population dynamics of the species.

Actions needed:

1. Protect and manage current populations.
2. Conduct research on potential management techniques and limiting factors.
3. Reintroduce in former range as needed to meet downlisting criteria.
4. Augment current populations.
5. Study ecology of the species.
6. Validate recovery objectives.

Total Estimated Cost of Recovery (\$1,000):

<u>Year</u>	<u>Need 1</u>	<u>Need 2</u>	<u>Need 3</u>	<u>Need 4</u>	<u>Need 5</u>	<u>Need 6</u>	<u>Total</u>
1996	147.5	0	0	0	0	0	147.5
1997	158.5	29	0	0	67	0	254.5
1998	74	29	0	0	67	0	170
1999	64	29	0	18	67	0	178
2000	66	29	0	18	67	0	180
2001	54	36	0	14	67	0	171
2002	118	7	0	14	43	0	182
2003	91	7	0	9	43	0	150
2004	86	7	17	9	43	0	162
2005	68	7	17	9	34	0	135
2006	84	0	21	9	34	12	160
2007	84	0	21	9	0	12	126
2008	82.5	0	21	9	0	12	124.5
2009	65.5	0	0	9	0	12	86.5
2010	65.5	0	0	9	0	12	86.5
2011	65.5	0	0	9	0	3	77.5
2012	65.5	0	0	9	0	3	77.5
2013	65.5	0	0	9	0	3	77.5

Total	1505	180	97	163	532	69	2546

Date of Recovery: To be determined once more is known about the biology and population dynamics of the species.

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PART I: INTRODUCTION

A. Brief Overview

Marsilea villosa Kaulf. (‘ihi‘ihi) is a fern endemic to the Hawaiian Islands and restricted to areas with irregular flooding regimes. It is also restricted to low elevations in areas that were most likely dryland forest or shrubland in the past but are now typically dominated by invasive alien vegetation.

Marsilea villosa has been reported from eleven populations, and is currently known from three populations on O‘ahu (one of these was planted within its historic range at Makapu‘u) and two populations on Moloka‘i, Hawai‘i. Threats to these populations include the encroachment of alien vegetation, habitat degradation by off-road vehicles, fire, development, small population size, and trampling and other impacts by humans and introduced mammals.

Due to its rarity and immediate threats, Marsilea villosa was federally listed as endangered, without the designation of critical habitat, on June 22, 1992 (USFWS 1992). Marsilea villosa is listed as endangered by the State of Hawai‘i (HRS 1950), the Hawaii Heritage Program ranks it as critically imperilled globally (G1) (Morse 1992), and it has been assigned a recovery priority number of 5 by the U.S. Fish and Wildlife Service (Service).

B. Species Description

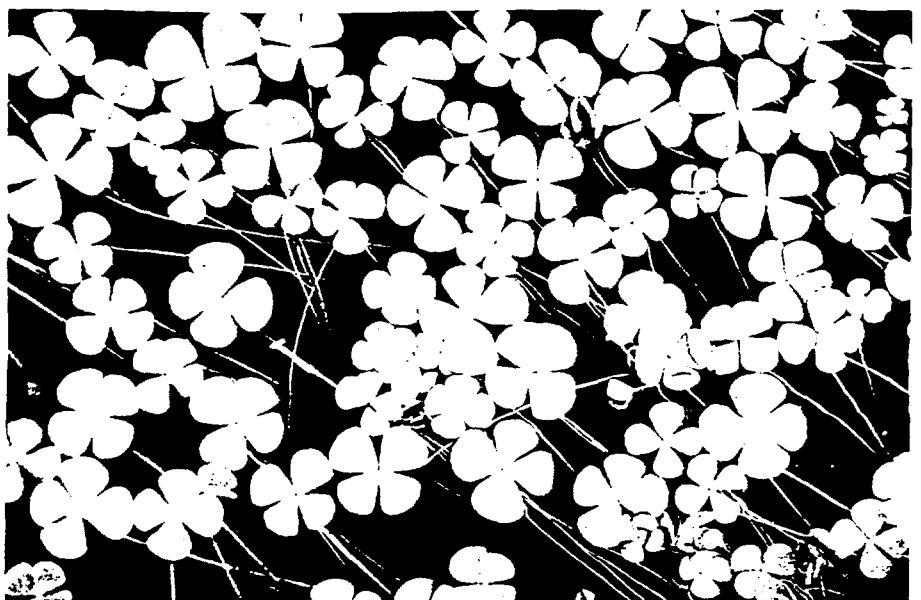
Marsilea villosa resembles a four-leaf clover, with four leaflets borne at the end of 1-45 centimeter (0.5-18 inch) tall leaf stalks (Figure 1). The leaves are borne in pairs along a thin rhizome. The leaves and rhizomes vary in pubescence, depending on the aridity of the habitat at the time of development. A hard sporocarp (hard-walled case containing male and female spores) is borne at the base of a leaf pair. The young sporocarp, like the rhizome, is covered with rust-colored hairs which are lost as the sporocarp matures. The plant occurs either in scattered clumps or as a dense interwoven mat, depending on the competition with other species for limited habitat resources.

Figure 1. Leaves of Marsilea villosa:

a. Emergent leaves.



b. Floating leaves.



C. Taxonomic Status

Marsilea villosa was first collected in 1817 by Louis Charles Adelbert von Chamisso during a Russian exploring expedition. It was described as Marsilea villosa by Georg Kaulfuss from Chamisso's O`ahu collections (Kaulfuss 1824). Since its description in 1824, there has been debate in the literature as to whether Marsilea villosa is a species endemic to the Hawaiian Islands, or merely a disjunct population of Marsilea vestita, known from western North America (Johnson 1986). Brackenridge (1854) and Mann (1866) considered M. villosa to be a subpopulation of M. vestita. Hillebrand (1888), MacCaughy (1918), Robinson (1912), Forbes (1920), Christensen (1926), Fosberg (1948), and Fosberg and Herbst (1975) considered M. villosa to be a species endemic to the Hawaiian Islands.

More recently Bruegmann (1986) and Johnson (1986) have treated Marsilea villosa as a separate, endemic species, most closely related to M. vestita. The characteristics separating Marsilea villosa are leaflets without concave lateral sides, and a truncately tipped sporocarp (Figure 2) (Bruegmann 1986). Though occasionally other species of Marsilea have been cited from the Hawaiian Islands in the late 1800's and early 1900's, these are no doubt misidentifications of M. villosa. Currently two or more non-native species of Marsilea are sold locally by garden shops.

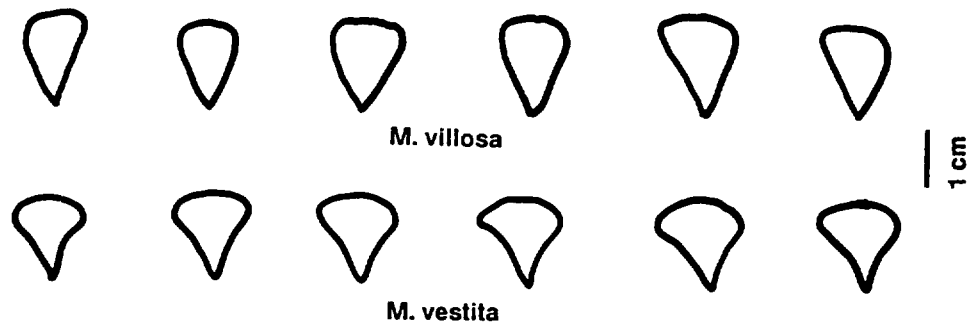
D. Distribution

Originally discovered on the island of O`ahu, Marsilea villosa has also been reported from the islands of Moloka`i and Ni`ihau. A total of eleven populations have been reported, of which only three currently occur on O`ahu and two currently occur on Moloka`i (Figure 3).

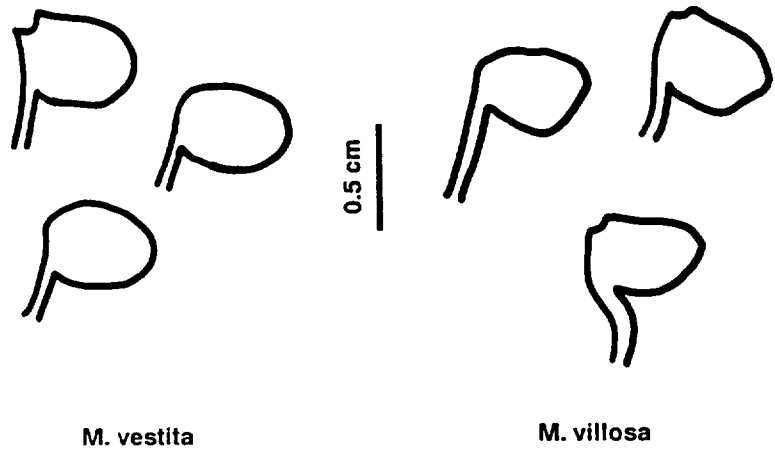
1. Historic Range

On O`ahu Marsilea villosa has been reported from Koko Head, Lualualei, `Ewa Plains, Nu`uanu Valley, Palolo Valley, and Makapu`u (Bruegmann 1986). The extirpated sites on O`ahu were destroyed by drainage of ponding areas, habitat degradation and competition from alien plants, and direct destruction from development.

Figure 2. Taxonomic characteristics distinguishing Marsilea villosa from M. vestita.

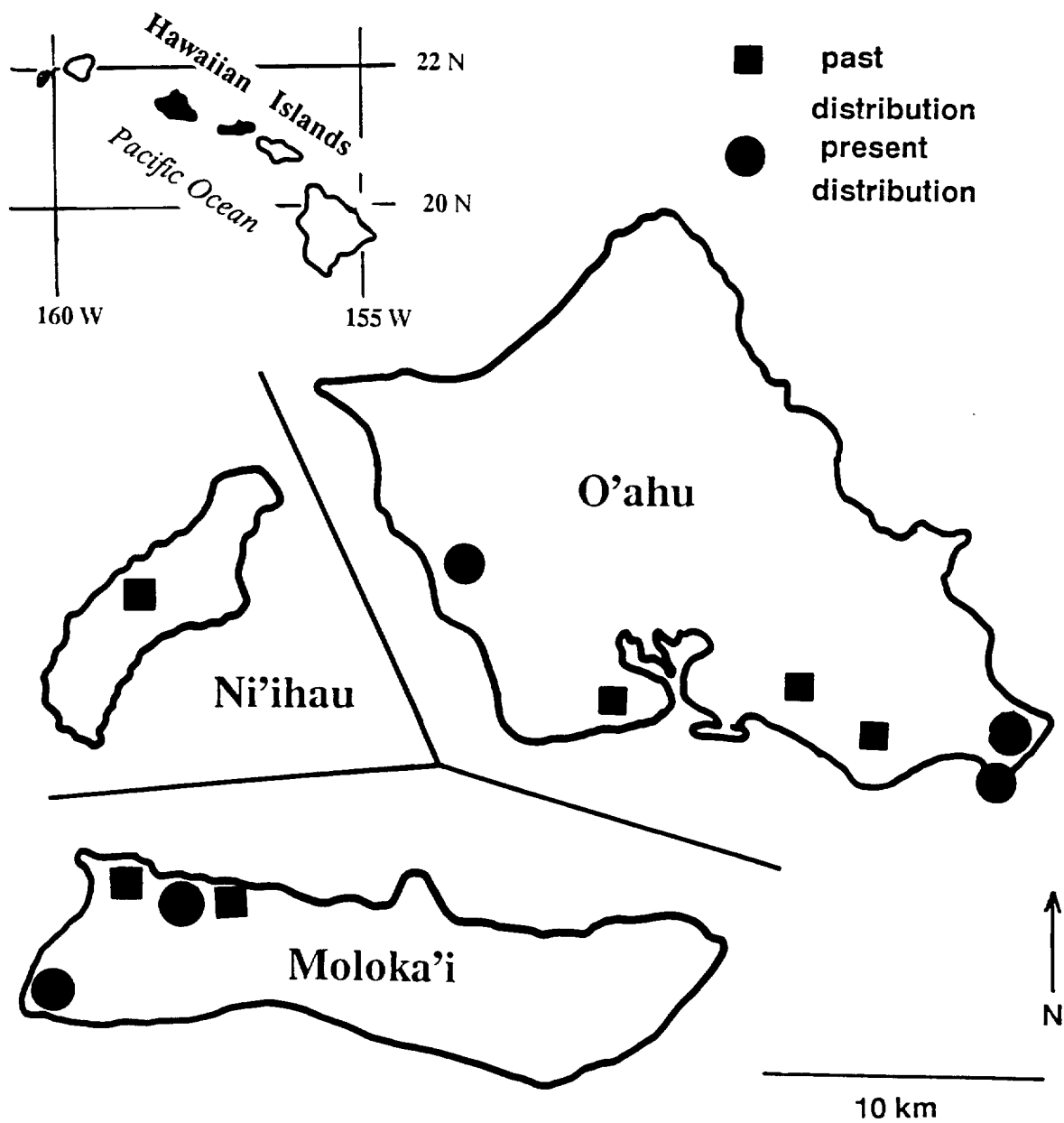


a. Leaflet shape.



b. Sporocarp shape.

Figure 3. Distribution of Marsilea villosa, past and present (base map in Atlas of Hawaii).



Three populations of Marsilea villosa have been reported from northwestern Moloka'i: at Moki'o in 1928; Mo'omomi in 1948; and 'Ilio Point during the mid-1970's (Bruegmann 1986). The Mo'omomi and 'Ilio Point populations have not been seen recently, even though the exact locality is known for the 'Ilio Point site. A fourth population was found in 1989 at Kamaka'ipo on southwestern Moloka'i (Char 1991). While cattle and/or deer have grazed all these areas heavily, the hydrology does not appear to be affected. It is possible that sporocarps are still in the soil and future ponding may result in new growth.

One population was reported at Loe Lake, on the island of Ni'ihau, in 1948 (Bruegmann 1986). It has not been verified since that time.

Only the populations discussed in the Current Range section of this plan will be treated as extant populations. The other populations mentioned in this section have not been confirmed to presently exist, and therefore will not be treated as extant populations in this plan.

2. Current Range

Currently, Marsilea villosa is known from only five populations. On O'ahu, it is naturally occurring at Koko Head and Lualualei. In addition, in the late 1980's, plants were taken from Koko Head and planted at Makapu'u. A small population was discovered in 1989 at Kamaka'ipo, near La'au Point on southwestern Moloka'i and another population was rediscovered in 1994 near Moki'o point on northwestern Moloka'i (M. Bruegmann, personal observation 1994).

3. Population Status

The Koko Head population occurs in Koko Head District Park, owned by the City and County of Honolulu. This is the largest contiguous population, comprising a solid mat of rhizomes covering 0.5 acre (0.2 hectares). The number of individuals is indeterminable, since the plants are intertwined and thickly matted. The City and County has a cooperative agreement with The Nature Conservancy of Hawaii to maintain and protect this population.

The Lualualei population occurs on land owned by the U.S. Navy. This population covers approximately 5-10 acres (2-4 hectares) in three subpopulations. The number of plants is unknown, but numbers at least in the hundreds.

The Makapu'u population is on land owned by Kamehameha Schools/B.P. Bishop Estate (Bishop Estate), leased to Kaiser Aluminum and Chemical Corporation. This population, which was planted in the late 1980's using plants taken from Koko Head, is scattered over an area of at least 1075 square feet (100 square meters) and is self-sustaining. The number of plants is unknown, but if clumped together would cover an area of approximately 537 square feet (50 square meters).

The Kamaka'ipo population on Moloka'i, discovered in 1989, is on land owned by Alpha U.S.A. Incorporated. It is a relatively small population, covering an area of only 175 square feet (16.3 sq. meters). The area was searched again in 1994, but no evidence of this population was found (M. Bruegmann, personal observation 1994). The soil appeared dry; consequently, there may not have been sufficient rain to stimulate leaf growth. Additional surveys following heavy rains and a thorough examination of the soils to ascertain whether sporocarps are present should be conducted.

The Moki'o population occurs on land owned by Moloka'i Ranch. This population covers approximately 5 acres (2 hectares) in three subpopulations.

E. Life History

Sexual reproduction of Marsilea villosa is initiated through the production of a hard sporocarp borne on the rhizome at a leaf pair node. The young sporocarp is covered with rust-colored hairs which are lost as the sporocarp matures. The sporocarp will mature only if the soil dries below threshold levels for leaf growth. The sporocarp remains in the soil for an extended period of time and must be scarified before it will open. It is not known how the sporocarp is scarified in Marsilea villosa, but bacterial action is thought to erode the wall of the sporocarp to the point that water can be absorbed and force the sporocarp open, as in other Marsilea species (Bold et al. 1980).

Standing water is necessary for the sporocarp to open and release the male and female spores. Standing water also is needed for the sperm to swim to the female spore containing the egg. For a detailed description of the reproduction process refer to Brueggmann (1986).

While flooding and sexual reproduction may occur yearly in other species, for Marsilea villosa this may occur as infrequently as once every ten or more years, due to the infrequency of sufficiently heavy rains in the lowland areas of Hawai'i where M. villosa occurs. This flooding cycle has probably remained consistent over time, since the hydrology of areas such as Koko Head has not been altered much historically. The first recorded flooding occurred in the winter of 1987-88 at Koko Head and Lualualei, and flooding occurred again in 1991 (M. Brueggmann, personal observation 1991). Sexual reproduction occurred with the first flood, resulting in the establishment of new plants as the water level receded. During flooding and the corresponding receding of the water level, the plants are particularly susceptible to disturbance. The second flooding did not result in any observed sexual reproduction. The exact cause of this failure to reproduce is unknown, but could be due to the fact that new sporocarps produced in the three years since the preceding flood had not had sufficient time to become abraded and therefore could not imbibe water.

In the initial development of Marsilea villosa from sexual reproduction, four different leaf types are observed. The first leaf to appear is linear, the second is spatulate, the third is two-lobed, and the fourth is the characteristic four-leaf clover shape. Survivorship studies under controlled conditions showed approximately 20% survivorship to the point where several mature leaves are observed (Brueggmann 1986). While survivorship has not been studied under field conditions, it is typically lower than that seen under controlled conditions. With survivorship of less than 20% under field conditions for sexually-produced plants and flooding as infrequent as once every ten or more years, vegetative reproduction is critical for the survival of Marsilea villosa.

The method of dispersal of Marsilea villosa sporocarps is unknown. Other species of Marsilea reportedly have been dispersed via waterbirds, both internally and externally (McAtee 1939, Malone and Proctor 1965). While waterbirds are not known to frequently visit areas where Marsilea villosa currently exists, Pacific plovers

(Pluvialis dominica) have been observed visiting the M. villosa population at Koko Head (Bruegmann 1988).

Marsilea villosa is different morphologically depending on the water level at the time of leaf development. Leaves floating in water develop no hairs, while in emergent or terrestrial leaves the lower surface may be completely covered with hairs (Figure 1). In addition, submerged and floating leaves tend to be thinner and larger than emergent or terrestrial leaves. The stalks of submerged leaves are very soft and flexible, while terrestrial leaves have very stiff, wire-like stalks.

The rhizomes similarly develop dense rust-colored hairs or scales at the nodes under dry conditions, but develop few if any under saturated or submerged conditions. The length of the rhizome between leaf nodes also varies with the availability of water. Under near-saturated to submergent conditions the rhizome grows rapidly and is extremely long, but the distance between nodes is almost non-existent under drier conditions.

In extremely dry conditions (soil moisture of less than 20%), the vegetative growth ceases and the leaflets dry and fall off. During the dry summer season only the brown leaf stalks remain standing, appearing like dry grass. Sufficient rain at any time of year stimulates new leaf and rhizome growth. Initially the leaves are nourished by carbohydrates stored in the rhizome, and if sufficient water does not remain available, the leaves will die before developing fully. The majority of the reproduction of Marsilea villosa occurs vegetatively, and rhizomes will fill all available soil surface if there is no shading or direct competition from other plants (Bruegmann 1986).

F. Habitat Description

Marsilea villosa requires periodic flooding for spore release and fertilization, then a decrease in water levels for the young plants to establish, and finally dry soil for sporocarps to mature. The species typically occurs in shallow depressions in clay soil, or lithified sand dunes overlaid with alluvial clay. All reported populations occur at or below 500 feet (150 meters) elevation. While Marsilea villosa can withstand minimal shading, it appears most vigorous growing in open

areas. The associated native vegetation of Marsilea villosa is unknown at all sites except Moki`o, since the native vegetation no longer exists at the other sites and was not recorded with the original collections. Each extant population for which information is currently available is discussed below.

1. Koko Head, O`ahu

At Koko Head (Figure 4), Marsilea villosa occurs in a very shallow depression named `Ihi`ihilauakea, which is the result of a volcanic vent that has been partially filled with alluvial soil. Most of the rainfall occurs during the winter months and averages less than 30 inches (80 centimeters) per year (Giambelluca et al. 1986).

Crustaceans and succinid snails are associated with Marsilea villosa at Koko Head. During the 1987-88 flooding, several species of crustaceans appeared. The crustaceans evidently survive the dry spells between floods by aestivating as subadults or eggs. The following groups were observed: ostracods (seed shrimp), cladocerans (waterfleas), conchostracans (clam shrimp), notostracans (tadpole shrimp), and copepods. In 1990 one succinid (land snail) also appeared. It is unclear where this came from, and whether it could survive the dry spells by aestivation. It is believed that all of these species are indigenous and may indeed be endemic, but further studies are needed to determine the genera and species represented (Chris Wammersly, University of Hawaii, Zoology Department, personal communication, 1988). The other sites have not been thoroughly searched during flooding, and may also support some or all of these invertebrates. It is unlikely that these species are obligate on Marsilea villosa, since they are also found in many other habitats. Whether Marsilea villosa is to any extent dependent on these invertebrates is unknown. The population is surrounded by introduced kiawe trees (Prosopis pallida), except for a small entrance on the east side of the crater. Marsilea villosa does send runners into the shade under the kiawe canopy, but plants in the shade are much less robust and do not extend into fully shaded areas. This is the only extant population where Marsilea villosa forms a dense mat. Within the Marsilea mat only one other native species can be found, `ilima (Sida fallax). The predominant alien plants associated with M. villosa are grasses. They include jungle rice grass (Echinochloa colonum), bristly foxtail (Setaria verticillata), cotton top (Digitaria insularis), Guinea grass (Panicum maximum), and Bermuda grass (Cynodon

Figure 4. *Marsilea villosa* habitat at Koko Head:



a. During dry, summer season.



b. During typical moist, winter season.



c. During infrequent flooding after heavy winter storms.

dactylon) (Wester 1989). Many of the alien plant species become established after disturbance, such as that caused by off-road vehicles, which disrupt the Marsilea mat and leave bare soil. Other species, such as Bermuda grass, can invade the dense mat of M. villosa.

Most of the alien plant species are killed by flooding, but jungle rice grass grows best under flooded conditions and dies back when the soil dries. There is a large seed bank of alien grasses in the soil and many sources of new seed in the surrounding area that prevent the complete elimination of the alien plant species.

2. Lualualei, O`ahu

The Lualualei population consists of three subpopulations. These subpopulations are approximately 0.25 miles (0.40 kilometers) apart and it is unknown whether they were ever one large continuous population. Individual plants of Marsilea villosa cannot be counted in all subpopulations, and it is unknown if adjacent individuals within a subpopulation are clonally or sexually established.

One subpopulation occurs (or occurred) on five acres (2 hectares) of the floodplain of Ma`ili`ili`i Stream in an area that was previously leased for cattle grazing. This subpopulation was scattered between individual kiawe trees that do not form a dense canopy. The cattle were removed in October 1992, and alien grasses (primarily Cenchrus ciliaris) now cover the area. No Marsilea villosa are currently evident; however, sporocarps and a few plants probably still remain. The second subpopulation is found on one acre (.4 hectares) in two small depressions that are mowed to maintain the area around Navy antennae. This subpopulation was unknown until the mowing occurred, opening up the site for the Marsilea to grow; it is found among alien grasses, at the edge of a kiawe forest. The third subpopulation is found in a rut along a road located on the northern side of the naval magazine. It is a small population of less than 100 square feet (9.3 square meters) which may have become established as a result of cattle carrying sporocarps from the first subpopulation to this site.

Most of the rainfall at the Lualualei site occurs in the winter months, and averages less than 30 inches (80 centimeters) a year (Giambelluca et al. 1986).

As at Koko Head, *ilima* is the only other native species remaining within the Marsilea population at Lualualei. The major alien plant species associated with Marsilea villosa include California grass (Brachiaria mutica), spiny amaranth (Amaranthus spinosus), Spanish needle (Bidens pilosa), jungle rice grass, bristly foxtail, and Guinea grass. Tadpole shrimp were observed at the second subpopulation in 1994 (M. Brueggemann, personal observation 1994).

3. Makapu'u, O'ahu

This population is located along a gently sloping drainage in lava substrate and shallow soil resembling gley. The plants are densest between boulders and in tire ruts along old jeep trails, where puddles of water occur after rainfall. Koa haole (Leucaena leucocephala) and other alien plant species are also present at this site.

4. Kamaka'ipo, Moloka'i

This population is located along a coastal jeep road in a site covered by grayish soil. There was evidence that standing water occurred in the 1988-89 rainy season (Char 1991). The population covers an area of 175 square feet (16.3 sq. meters) (Char 1991), and receives approximately 15 inches (40 centimeters) of rain annually (Giambelluca et al. 1986). The number of individuals is unknown. Associated species include Bermuda grass and the indigenous Cressa truxillensis.

5. Moki'o, Moloka'i

This population consists of three subpopulations which are approximately 0.1 miles (0.16 kilometers) apart. Subpopulation 1 is on a south-facing slope and consists of Marsilea scattered over approximately 80 by 30 feet (24.3 by 9.1 meters). Subpopulation 2 is located on a northwest-facing slope and is scattered over an area of approximately 50 by 30 feet (15.2 by 9.1 meters), with some portions extremely dense under stunted kiawe trees. Subpopulation 3 is on a north-facing slope and is scattered over an area of approximately 120 by 30 feet (36.6 by 9.1 meters).

This population exists on rocky hillsides of 5 to 20 percent slope with shallow clayey soils among rocks. Rainfall is less than 15.8 inches (40 centimeters) per year according to Giambelluca et al. (1986). The habitat of the three subpopulations is very similar and all occur at approximately 500 feet (152.4 meters) elevation.

All three subpopulations of Marsilea villosa at Moki`o have stout rhizomes, indicating several years of growth. Sporocarps were found in subpopulations #2 and #3, and most of these were immature, with dense coverings of villose hairs. How sexual reproduction occurs at this site is unknown, since the plants are all found on slopes that do not appear to allow ponding of water. The associated species are very similar between subpopulations, although the vegetation at subpopulation 3 has few if any woody species and is dominated more by the indigenous pili grass (Heteropogon contortus) than the other subpopulations. The only other native species found in these areas are 'ilima (Sida fallax) and uhaloa (Waltheria indica). Alien plant species associated with Marsilea villosa are buffelgrass (Cenchrus ciliaris), kiawe, lantana (Lantana camara), cotton top (Digitaria insularis), Japanese tea (Chamaecrista nictitans), scarlet pimpernel (Anagallis arvensis), and Portulaca pilosa. Just east of subpopulation 3, one plant of the endangered Centaurium sebaeoides (recovery will be addressed in the Waianae Cluster Recovery Plan) was observed in flower. Two endemic species, Tetramolopium sylvae and Schiedea globosa, were observed on the cliffs adjacent to the area.

G. Reasons for Decline and Current Threats

The major threats to Marsilea villosa are destruction of natural hydrology; development; habitat degradation and resultant competition from invading alien plant species; off-road vehicles; fire; small population size and fragmentation; and trampling and other impacts from humans and introduced mammals.

The majority of the historical sites were destroyed by alteration of hydrological patterns and/or by development. The Palolo Valley site was a vacant lot, which is now covered by a residential dwelling. The `Ewa Plains population disappeared after the area was drained for development.

Unfortunately, the incidental take permit provisions of the Endangered Species Act of 1973, as amended (Act) [section 10(a)(1)(B)] do not apply to listed plants and the State of Hawaii has no incidental take provision within their law. Therefore, although destruction of listed plants is prohibited by State law, this is hard to enforce, and development projects have proceeded in the past with no accompanying conservation plans or mitigation.

Habitat degradation and competition from invading alien plant species is a threat to all five Marsilea villosa populations. Alien plant species present an even greater threat to the populations where the Marsilea are more scattered, allowing the alien plants to outcompete Marsilea more easily.

Fire presents a potential threat to all five Marsilea populations, especially during dry periods, when most of the biomass is dead and easily flammable. A small fire started from a cigarette did occur at the Koko Head population in the summer of 1983, burning an area of approximately 5.4 sq. feet (.5 meters). Marsilea villosa was eventually replaced in this area by alien plant species (M. Bruegmann, personal observation 1983). Approximately half of the Ma'ili'ili'i subpopulation burned in 1989 and was replaced by alien plants adapted to fire (M. Bruegmann, personal observation 1991).

Being sold by the nursery trade is also a threat to Marsilea villosa. Other species of Marsilea from Asia are currently in the nursery trade in Hawai'i and because M. villosa is an attractive plant, it may be of interest to researchers, curiosity seekers, or collectors of rare or aquatic plants.

Threats specific to each population are discussed below.

1. Koko Head Population.

Currently, the Koko Head site is being considered for development of a water storage facility, which would pump water from the underground aquifer in the area (Carolyn Corn, Hawaii Department of Land and Natural Resources, personal communication 1993). If pumping is allowed to occur, it would affect the hydrology of the area and perhaps prevent future flooding of the Koko Head population.

Mongoose (Herpestes auropunctatus) have been seen in the Koko Head area (M. Bruegmann, personal observation 1985), and the Marsilea villosa population has recently shown evidence of burrows and animal pathways, which are likely destroying the Marsilea in the immediate area and opening up sod, allowing alien plants to grow within the mat (Buck 1993).

The Koko Head site is also threatened by off-road vehicles. Because alien species can only gain a foothold where disturbance has created a gap in the Marsilea mat, the invasion by alien plant species has been greatly accelerated at this site from off-road vehicles. In areas where the off-road vehicles have not disturbed the thick mat, Marsilea can successfully compete with alien plant species. A sign and barrier have been erected at the entrance to the crater to deter off-road vehicle use of this area. This deterrent has been successful, but constant monitoring is needed to maintain the barriers.

Koko Head is one of the two sites that are easily accessible to hikers, and increased foot traffic could be an additional threat to this population.

2. Lualualei Population.

Although it is not known whether the three Lualualei subpopulations ever existed as one population, their small size and fragmentation are threats to this population.

Cattle previously ranged freely through the Ma`ili`ili`i subpopulation at Lualualei. Although they did not appear to feed on Marsilea villosa, trampling may have caused permanent damage. Following listing of Marsilea, cattle were removed from the Ma`ili`ili`i subpopulation. Since then, alien grasses have outcompeted and displaced Marsilea (M. Brueggmann, personal observation 1994). This would suggest that even though trampling may be detrimental to Marsilea villosa, cattle may serve to reduce the competition with alien plant species. Cattle are still present at the third subpopulation and, therefore, continue to be a threat.

Mowing the area around the Navy antennae may also be a threat to the Marsilea subpopulation that exists in this location; however, this subpopulation was unknown until the mowing occurred. Even though mowing may be detrimental to Marsilea villosa, mowing may also serve to reduce competition with alien plant species.

3. Makapu`u Population.

Although there are no known development projects currently planned that would affect the Makapu`u population, this area has been considered for development in the past

and may be considered for development in the future. Such possible development presents a potential threat until the land is adequately protected.

Like Koko Head, Makapu'u is easily accessible to the public. Off-road vehicles and increased foot traffic present additional threat to this population, especially since the plants occur in jeep ruts.

4. Kamaka'ipo Population.

The largest threat to the Kamaka'ipo population is development. The site is owned by Alpha U.S.A. Incorporated, which has plans to start development soon (Winona Char, Char & Associates Biological Consultants, personal communication 1992). However, the development company is willing to maintain the population and carry out reintroductions of this species to other, more protected sites (Sanburn 1991).

Axis deer at the Kamaka'ipo site are believed to browse and trample Marsilea villosa, which may cause permanent damage to individual plants and decrease the species' ability to compete with alien plant species.

5. Moki'o Population.

Axis deer and cattle, which are present at this site, may trample and browse Marsilea villosa, causing permanent damage to individual plants and decreasing the species' ability to compete with alien plants (M. Brueggmann, personal observation 1994).

This population is further threatened by its small size and fragmentation, and possible development projects.

H. Conservation Efforts

1. Federal Actions

Marsilea villosa was listed as endangered, with no critical habitat, under the Endangered Species Act on June 22, 1992 (57 FR 27863), and, therefore, is afforded the protection of this Act.

The Navy has undertaken some conservation measures in protecting the population of Marsilea that occurs at Lualualei. These measures include monitoring, and the removal of cattle from one subpopulation in October 1992.

In April 1994, U.S. Fish and Wildlife Service biologists, M. Bruegmann and E. Sharpe, and Department of Forestry and Wildlife biologist, R. Hobdy, searched the northwest coast near the area of Moki'o Point and were able to locate the Moki'o population described earlier in this plan, which had not been seen since 1928 (M. Bruegmann, personal observation 1994).

2. State Actions

Marsilea villosa is listed as endangered by the State of Hawaii (HRS 1950). This law prohibits the destruction or taking of listed plants. However, no populations of Marsilea villosa occur on State lands.

3. City and County and Nongovernmental Actions

Major conservation efforts have taken place at the Koko Head population of Marsilea villosa. The City and County of Honolulu and The Nature Conservancy of Hawaii entered into a cooperative agreement for the protection of the 'Ihi'ihilauea Preserve in 1986. The City and County owns the land and provides needed materials, and The Nature Conservancy oversees the management. Labor is supplied by volunteers from the Hawaiian Botanical Society and The Nature Conservancy. A sign and barrier have been erected at the entrance to the crater. Native wiliwili (Erythrina sandwicensis) seedlings have been planted around the barriers to provide a maintenance-free barrier in the future.

Volunteers have manually removed alien plant species during the winter growing seasons from 1987-1991. Lyndon Wester of the University of Hawai'i Geography Department has conducted yearly monitoring of the site since 1987 to determine the effectiveness of the weeding programs. The results of weeding on the alien species within the populations are limited. Initial weeding following the 1987-88 flood appeared beneficial, but because most of the alien plant species do not survive standing water, the subsequent flood may have killed more weeds than hand-weeding. The only alien plant species not adversely affected by the flooding was jungle rice grass, which thrives in saturated soils, but dies back during drought (the major portion of the year at Koko Head). As a result of this monitoring, weeding was

suspended in the spring of 1991, since it appeared that manual removal of alien plant species did not have a significant beneficial effect on the health of the population at this time (Morgan 1993). However, monitoring is continuing to determine if manual control may become necessary in the future.

The developers who own the Kamaka`ipo property are aware of the population and are willing to undertake some conservation measures. They have already adjusted their condominium and golf course development plans to avoid the Marsilea villosa population.

In 1984, searches were conducted by M. Brueggmann and K. Asherman (graduate students at the University of Hawaii) along the coast of Moloka`i to relocate the three populations on northwest Moloka`i but did not result in the rediscovery of these populations (M. Brueggmann, personal observation 1984). Additional surveys following heavy rains should be conducted along the coast in the areas of Ili`o point and Mo`omomi. In addition, a thorough examination of the soils should be conducted, to ascertain whether sporocarps are present.

Marsilea villosa can be grown from rhizomes and from sporocarps (Brueggmann 1986). Waimea Arboretum and Botanical Garden, as a Participating Institution of the Center for Plant Conservation, and the National Tropical Botanical Garden are currently growing plants from the Koko Head population. These plants are part of the Center's National Collection of Endangered Plants, which is intended to conserve genetically representative samples of rare plants ex situ. This material is available for research, education, and reintroduction.

I. Strategy of Recovery

Recovery of Marsilea villosa is based on a multi-faceted strategy of site protection and management (on a case-by-case basis), threat reduction, and ex situ protection to ensure the continued existence of this species.

The most important recovery tasks for the conservation of Marsilea villosa involve the protection and management of the species in the wild. While adequate additional native habitat may no longer exist, it is possible to enhance existing habitat by

removing threats. At all sites, the primary management concerns are the protection of habitat, control of alien plant species, and prevention of fire.

In addition to protection of the wild populations, genetically representative samples of all extant populations should be maintained in living cultivation at Waimea Arboretum and Botanical Garden and through long-term storage of sporocarps. This material will be used for research, education, and reintroduction / augmentation of wild populations.

PART II. RECOVERY

A. Recovery Objectives and Criteria

1. Objectives

The recovery of Marsilea villosa will require a long term commitment in terms of management and monitoring, since reproductive success can only be measured following heavy rains, which occur as infrequently as every ten or more years in areas where M. villosa occurs.

The immediate objective of this plan is to protect habitats and stabilize the currently extant populations. Actions required will include halting the spread of invasive alien plant species, preventing fire, and ensuring the maintenance of current flooding regimes at all five sites by preventing deleterious changes in the local geohydrologic cycle. The ultimate objective of this plan is to delist Marsilea villosa.

2. Criteria

a. Downlist to threatened status

Marsilea villosa will be considered for downlisting when at least six geographically distinct, self-sustaining populations (three on O`ahu and three on Moloka`i or three on O`ahu, two on Moloka`i, and one on Ni`ihau) are adequately protected and have been maintained through two successive floods resulting in sexual reproduction. The year of downlisting is therefore dependent on rainfall and cannot be predicted at this time. A population will be considered to be self-sustaining when it is observed to be successfully reproducing, both vegetatively and sexually, and the population size is stable or increasing.

b. Delist

Marsilea villosa will be considered for delisting when active management is no longer needed to maintain the downlisting criteria for six populations. More detailed criteria for delisting Marsilea villosa will be established once more is known about the biology and population dynamics of the species.

The recovery objectives and criteria should be reconsidered after five years, when more biological data on the species are available.

B. Step-Down Outline

1. Protect and manage the 5 known populations of Marsilea villosa.

- 11. Protect and manage the 3 populations on O`ahu.
 - 111. Protect the Koko Head population.
 - 112. Protect the Lualualei population.
 - 113. Protect the Makapu`u population.
 - 114. Control threats to the Koko Head population.
 - 1141. Monitor and control development projects.
 - 1142. Control mongoose.
 - 1143. Control alien plants.
 - 1144. Limit human trampling and off-road vehicle use.
 - 1145. Reduce the risk of catastrophic fire.
 - 115. Control threats to the Lualualei population.
 - 1151. Develop an Endangered Species Management Plan for Lualualei site.
 - 1152. Monitor and control activities, such as development projects, affecting the Lualualei site.
 - 1153. Control grazing and trampling by cattle.
 - 1154. Monitor and control mowing.
 - 1155. Control alien plants.
 - 1156. Reduce the risk of catastrophic fire.
 - 116. Control threats to the Makapu`u population.
 - 1161. Monitor and control development projects.
 - 1162. Control alien plants.
 - 1163. Limit human trampling and off-road vehicle use.
 - 1164. Reduce the risk of catastrophic fire.
- 12. Protect and manage the two extant populations on Moloka`i.

- 121. Conduct additional surveys at Kamaka`ipo site.
- 122. If extant, protect the Kamaka`ipo population.
- 123. Protect the Moki`o population.
- 124. Control threats to the Kamaka`ipo population, if extant.
 - 1241. Monitor and control development projects.
 - 1242. Control deer.
 - 1243. Control alien plants.
 - 1244. Reduce the risk of catastrophic fire.
- 125. Control threats to the Moki`o population.
 - 1251. Monitor and control development projects.
 - 1252. Determine habitat factors limiting the three subpopulations from becoming one contiguous population.
 - 1253. Control deer and cattle.
 - 1254. Control alien plants.
 - 1255. Reduce the risk of catastrophic fire.
- 13. Conduct annual monitoring.
- 14. Provide information and education for the nursery industry.
- 15. Preserve genetic stock.
- 2. Protect and manage at least one population in historic range at Loe Lake site on Ni`ihau or on northwestern Moloka`i.
 - 21. Attempt to ascertain whether population still exists at Loe Lake on Ni`ihau.
 - 211. Survey the site.
 - 212. Ascertain whether sporocarps are present.
 - 22. If the population is still present on Ni`ihau, protect and manage.
 - 221. Protect the Ni`ihau population.
 - 222. Control threats to the Loe Lake population.
 - 2221. Control grazing and trampling by cattle, pigs, and sheep.

- 2222. Control alien plants.
- 2223. Reduce the risk of catastrophic fire.
- 223. Preserve genetic stock.
- 23. Attempt to ascertain whether populations still exist in northwestern Moloka`i.
 - 231. Survey the Mo`omomi site.
 - 232. Survey the `Ilio site.
 - 233. Ascertain whether sporocarps are present.
- 24. Collect vegetative material and/or sporocarps from all extant populations on Moloka`i.
- 25. If one or more of the populations are still present on northwest Moloka`i, protect and manage.
 - 251. Protect the Mo`omomi site, if appropriate.
 - 252. Protect the `Ilio site, if appropriate.
 - 253. Control threats to the northwestern Moloka`i populations.
 - 2531. Control grazing and trampling by cattle and/or deer.
 - 2532. Control alien plants.
 - 2533. Reduce the risk of catastrophic fire.
- 3. Conduct research on potential management techniques and limiting factors.
 - 31. Determine the effects of changes in hydrology of sites.
 - 32. Develop methods and procedures for preventing or controlling changes in hydrology.
 - 33. Develop methods to control alien plants.
 - 34. Develop methods to control introduced mammals.
- 4. If populations no longer exist, develop reintroduction plan for Ni`ihau and/or northwest Moloka`i.
 - 41. Develop and implement reintroduction plan for Ni`ihau.
 - 42. Develop and implement reintroduction plan in northwestern Moloka`i.

5. Augment populations, as appropriate.
 51. Develop augmentation plan for O`ahu populations.
 52. Develop augmentation plan for Moloka`i populations.
 53. Develop augmentation plan for Loe Lake, if appropriate.
 54. Implement augmentation plans, as appropriate.
6. Study the ecology of the species.
 61. Determine moisture and other requirements governing reproduction and maintenance.
 62. Conduct soil analysis.
 63. Study long-term demography.
 64. Determine genetic variability.
 65. Determine minimum viable population size.
 66. Determine association with native and non-native invertebrates.
 67. Determine dependence upon and/or association with native and non-native birds.
7. Verify recovery objectives.
 71. Verify the number of individuals and populations needed to downlist and to delist.
 72. Revise the recovery objectives as needed.

C. Step-Down Narrative

1. Protect and manage the 5 known populations of Marsilea villosa.

The first step in recovering Marsilea villosa must be protection and management of the populations known to be currently extant. These populations must be afforded long-term security, and the threats acting upon them must be understood and controlled.

11. Protect and manage the 3 populations on O`ahu.

It is important to protect, in perpetuity, the three extant populations on O`ahu, through negotiations and partnerships with the landowners.

111. Protect the Koko Head population.

The Koko Head population is currently managed by The Nature Conservancy for the City and County of Honolulu under the provisions of a short-term conservation agreement. This agreement should be converted to a long-term agreement to be effective.

112. Protect the Lualualei population.

The U.S. Navy is required by section 7 of the Act to insure that any action authorized, funded, or carried out by the Navy is not likely to jeopardize the continued existence of any endangered or threatened species. Section 7 further stipulates that all federal agencies utilize their authorities in furtherance of the purposes of the Act by carrying out programs for the conservation of listed species. The Navy should be encouraged to develop an Endangered Species Management Plan for Lualualei and undergo section 7 consultation with the Service for any actions likely to affect Marsilea at this site.

113. Protect the Makapu`u population.

The Service should explore all avenues of cooperation and partnership with Bishop Estate for the long-term protection and management of this population.

114. Control threats to the Koko Head population.

The threats from development projects, mongoose, alien plants, human trampling, off-road vehicle use, and fire should be controlled at the Koko Head site.

1141. Monitor and control development projects.

The site should be monitored and activities detrimental to the site controlled through appropriate regulatory measures. The State of Hawaii should be encouraged to develop an incidental take permitting process to allow for better planning of development projects and mitigation for listed plants.

1142. Control mongoose.

Set traps and implement most effective methods of control as the results of research conducted in Tasks #33 and #36 dictate.

1143. Control alien plants.

This population has not required manual weed removal since 1989 (Wester 1991), because most of the alien plant species were killed by flooding. However, it may be necessary to return to alien plant removal during the long interim between floods. Continual monitoring of the existing permanent plots is necessary to assess the spread of alien plant species and to determine if control is again necessary as conditions change. If it is determined that control measures need to be reinitiated, the most effective methods of control should be implemented (based on results of Task #33).

1144. Limit human trampling and off-road vehicle use.

This population is easily accessible to the public. Access need not be excluded totally. It is possible to limit public access to the edge of the population, while minimizing the effects on the population.

Public education is an important tool in limiting human trampling and off-road vehicle use and should include interpretive signs and hiking trails. Field trips should be encouraged through conservation organizations in the community that can interpret the significance of the population.

1145. Reduce the risk of catastrophic fire.

The site should be surveyed to determine the magnitude of the fire hazard and, if required, the fuel load reduced. Reduction of the fuel load may be accomplished by removing all alien plants (Task #1143). Fire emergency plans should be developed and fire breaks constructed where appropriate.

115. Control threats to the Lualualei population.

The threats from development projects, fragmentation, grazing and trampling by cattle, alien plants, and fire should be controlled at the Lualualei site.

1151. Develop an Endangered Species Management Plan for Lualualei site.

A detailed Endangered Species Management Plan should be developed for the Lualualei site. Presently, the Navy addresses Marsilea as a candidate 1 species under the Act in their 1987 Natural Resources Management Plan; the management plan developed

in this task should be used to update that section of the Natural Resources Management Plan.

The Endangered Species Management Plan would include management options specific to the site. For example, the three subpopulations are close enough together (within approximately .25 miles) that managing them as one contiguous population may be possible. This should be investigated. Other tasks to be detailed in the management plan are outlined below.

1152. Monitor and control activities such as development projects affecting the Lualualei site.

The Lualualei site should be monitored and activities detrimental to the population should be controlled through section 7 consultation.

1153. Control grazing and trampling by cattle.

Grazing and trampling by cattle should be controlled by fencing an appropriate area or revoking the grazing lease and removing all cattle (but see Task #1155 below). Stringent control of alien plants *must* be conducted in conjunction with cattle removal.

1154. Monitor and control mowing.

Mowing should be very carefully monitored at the antenna site to ensure that no Marsilea are mistakenly damaged or destroyed and that only alien plants are negatively impacted.

1155. Control alien plants.

The population must be protected from alien plant competitors by physically removing all alien plants on a continual basis. The possibility of reintroducing ungulates on a limited basis to control alien grasses at the previously grazed Ma'ili'ili'i Stream subpopulation should be considered. If more effective methods of control are discovered in Task #34, these should be implemented.

1156. Reduce the risk of catastrophic fire.

See narrative for Task #1145.

116. Control threats to the Makapu'u population.

The threats from development projects, alien plants, human trampling, off-road vehicle use, and fire should be controlled at the Makapu'u site.

1161. Monitor and control development projects.

See narrative for Task #1141.

1162. Control alien plants.

See narrative for Task #1155.

1163. Limit human trampling and off-road vehicle use.

See narrative for Task #1144.

1164. Reduce the risk of catastrophic fire.

See narrative for Task #1145.

12. Protect and manage the two current populations on Moloka'i.

It is important to protect, in perpetuity, the two populations on Moloka'i, through negotiations and partnerships with the landowners.

121. Conduct additional surveys at Kamaka'ipo site.

Additional surveys following heavy rains and a thorough examination of the soils should be conducted to ascertain whether sporocarps are present and the population extant.

122. If extant, protect the Kamaka'ipo population.

Long-term protection and management of the land at the Kamaka'ipo site needs to be ensured via an agreement with Alpha U.S.A. Inc.

123. Protect the Moki'o population.

Long-term protection and management of the land at the Moki'o site needs to be secured via an agreement with Moloka'i Ranch.

124. Control threats to the Kamaka'ipo population, if extant.

The threats from development projects, deer, alien plants, and fire should be controlled at the Kamaka'ipo site, if extant.

1241. Monitor and control development projects.

See narrative for Task #1141.

1242. Control deer.

Browsing and trampling by deer should be controlled by constructing and maintaining a deer-proof fence. The fence around the Kamaka'ipo site should be large enough to enclose the area needed to attain the recovery objective for this

population. If more effective methods to control deer are determined in Task #34, they should be implemented. This task should be conducted only in conjunction with the control of alien plants.

1243. Control alien plants.

See narrative for Task #1155.

1244. Reduce the risk of catastrophic fire.

See narrative for Task #1145.

125. Control threats to the Moki'o population.

The threats from possible development projects should be investigated and controlled if necessary. The possibility of making the three subpopulations one contiguous population should also be investigated and the threats from deer, cattle, alien plants, and fire should be controlled.

1251. Monitor and control development projects.

The landowners (Moloka'i Ranch Inc.) should be contacted and the possible threats from development projects should be investigated and controlled if necessary. See narrative for Task #1141.

1252. Determine habitat factors limiting the three subpopulations from becoming one contiguous population.

The three subpopulations are close enough together and the intervening habitat apparently similar enough that managing the subpopulations as one contiguous population may be possible. Microhabitat features within and between populations should be compared to determine, and possibly alleviate, differences in physical (eg. micro-topographical), chemical, or other factors that may be limiting growth of Marsilea in the intervening habitat.

1253. Control deer and cattle.

Grazing and trampling by cattle and deer should be controlled by fencing an appropriate area to allow the population to recover. See narrative for Task #1242.

1254. Control alien plants.

See narrative for Task #1155.

1255. Reduce the risk of catastrophic fire.

See narrative for Task #1145.

13. Conduct annual monitoring.

All five populations should be monitored annually during the winter rainy season to check on the vigor of the population and assess the results of threat management.

14. Provide information and education for the nursery industry.

Education of the nursery industry is also critical. Other species of Marsilea from Asia are currently in the nursery trade in Hawai'i. While attempts to hybridize Marsilea villosa with M. vestita were unsuccessful (Bruegmann 1986), hybrids between other species of Marsilea have been reported (Johnson 1986, Buchholz and Selett 1941). The nursery industry should be encouraged to eliminate all Marsilea from their stocks, unless future proposed changes in state law allow propagation of endangered plants..

15. Preserve genetic stock.

Vegetative material and/or sporocarps should be collected from all extant populations of Marsilea villosa. Protection of the gene pool should be accomplished through long-term storage of sporocarps and by maintaining material in cultivation. This will act as a back-up in case stochastic events destroy one or more populations. Genetic material should be preserved as living clonal material to maintain the original makeup of the wild populations. In addition, long-term storage of sporocarps is critical for maintaining long-term genetic diversity. Waimea Arboretum and Botanical Garden should perform this task as part of its Center for Plant Conservation program. Propagation of these plants should not be considered a substitute for protecting the species in the wild.

2. Protect and manage at least one population in historic range at Loe Lake site on Ni'ihau or on northwestern Moloka'i

In order to fulfill the recovery objective, at least one population within the historic range, at Loe Lake on Ni'ihau or on northwestern Moloka'i, needs to be protected and managed.

21. Attempt to ascertain whether population still exists at Loe Lake on Ni'ihau.

Steps should be taken to ascertain whether the historic population of Marsilea villosa still exists at Loe Lake on Ni'ihau. Prior to surveys, permission must be attained from the landowner.

211. Survey the site.

The historic range of Marsilea villosa at Loe Lake should be intensively surveyed for the plant following heavy rains. The

landowner should be encouraged to conduct such surveys and assisted in every way possible.

212. Ascertain whether sporocarps are present.

If surveys for the presence of *M. villosa* vegetative material fail to locate the Loe Lake population, a thorough soil analysis should be conducted, at least one foot (.3 meters) deep, to ascertain whether sporocarps are present.

If the soil analysis fails to locate the sporocarps, a control plot within the historical site should be artificially irrigated to determine whether plants or sporocarps are present.

22. If the population is still present on Ni`ihau, protect and manage.

If the population is still present at Loe Lake on Ni`ihau, it is important that it be protected and managed, in perpetuity, through negotiations and partnerships with the landowner.

221. Protect the Ni`ihau population.

Protection and management of the land at the Loe Lake site needs to be secured via a long-term agreement with the landowner.

222. Control threats to the Loe Lake population.

The threats from introduced mammals, alien plants, and fire should be controlled at the Loe Lake site.

2221. Control grazing and trampling by cattle, pigs, and sheep.

Grazing and trampling by cattle, pigs, and sheep should be controlled by constructing and maintaining a fence and removing all mammals from the enclosure. The area enclosed by the fence should be large enough to attain the recovery objective for this population. The control of mammals must be accompanied by alien plant control. If more effective methods of control are determined in Tasks #33 and #36, these should be implemented.

2222. Control alien plants.

See narrative for Task #1155.

2223. Reduce the risk of catastrophic fire.

See narrative for Task #1145.

223. Preserve genetic stock.

See narrative for Task #14.

23. Attempt to ascertain whether the two additional historical populations still exist in northwestern Moloka'i.

Steps should be taken to ascertain whether the Mo'omomi and 'Ilio point populations of Marsilea villosa still exist in northwestern Moloka'i. Prior to surveys, permission must be attained from The Nature Conservancy of Hawaii for the Mo'omomi site, and Moloka'i Ranch Inc. for the 'Ilio Point site.

231. Survey the Mo'omomi site.

The historic range of Marsilea villosa at Mo'omomi should be intensively surveyed for the plant following heavy rains. The landowner should be encouraged to conduct such surveys and assisted in every way possible.

232. Survey the 'Ilio site.

The historic range of Marsilea villosa at 'Ilio point should be intensively surveyed for the plant following heavy rains. The landowner should be encouraged to conduct such surveys and assisted in every way possible.

233. Ascertain whether sporocarps are present.

If surveys for the presence of M. villosa vegetative material fail to locate the northwestern Moloka'i populations, a thorough soil analysis should be conducted, at least one foot (.3 meters) deep, to ascertain whether sporocarps are present.

If the soil analysis fails to locate sporocarps, a control plot within the historical range should be artificially irrigated to determine whether plants or sporocarps are present.

24. Collect vegetative material and/or sporocarps from all extant populations on Moloka'i.

Vegetative material and/or sporocarps should be collected from all newly discovered or re-discovered sites for the preservation of genetic stock. See narrative for Task #15.

25. If one or more of the two additional historical populations is still present on northwest Moloka'i, protect and manage.

If one or more populations is still present on northwest Moloka'i, it is important that at least one be protected, in perpetuity, through negotiations and partnerships with the landowners.

251. Protect the Mo'omomi site, if appropriate.

If appropriate, long-term protection and management of the land at the Mo'omomi site needs to be secured via an agreement with The Nature Conservancy.

252. Protect the `Ililo site, if appropriate.

If appropriate, long-term protection and management of the land at the `Ililo site needs to be secured via an agreement with Moloka'i Ranch Inc.

253. Control threats to the northwestern Moloka'i populations.

The threats from cattle, deer, alien plants, and fire should be controlled at the appropriate northwestern Moloka'i sites.

2531. Control grazing and trampling by cattle and/or deer.

See narrative for Task #1253.

2532. Control alien plants.

See narrative for Task #1155.

2533. Reduce the risk of catastrophic fire.

See narrative for Task #1145.

3. Conduct research on potential management techniques and limiting factors.

Factors limiting growth and reproduction should be determined and more effective methods of control developed in order to create an adequate management and threat-control program. It is particularly important to determine the relative impact of each hypothesized threat on the survival and reproduction of Marsilea villosa.

Potential management techniques for M. villosa should be tested to determine their effectiveness. The selection of experimental management techniques should be based on the known needs for each population. In addition, with so little known about the biology and habitat requirements of M. villosa and with so little left in the wild, off-site experimentation is the best way to initially determine the most appropriate management methods for each population. The experimental treatment should be applied within replicated plots. The number and size of the plots should be determined by the size of the population and the density of the plants. An equal number of unmanipulated plots should be established as controls. The possibility of establishing experimental plots near the Lualualei population, in cooperation with the Navy, should be explored.

31. Determine the effects of changes in hydrology of sites.

Hydrological regime is probably the most important factor affecting the growth, maintenance and reproduction of Marsilea villosa populations. Determination of the effects of changes in the hydrology of the sites where Marsilea villosa occurs will better enable managers to plan for and control the effects that are shown to limit the growth and reproduction of M. villosa.

32. Develop methods and procedures for controlling changes in hydrology.

Based on the results of Task #31, methods and procedures for controlling changes in hydrology that have been shown to limit the growth and reproduction of M. villosa should be developed and implemented, where appropriate. Whenever possible, changes to the hydrology of Marsilea villosa sites should be avoided altogether.

33. Develop methods to control alien plants.

Improved methods must be developed to control alien plant species. Alien plant species control should be conducted at various times through the growing season to determine the most effective time for removal and the time of least damage to the Marsilea villosa (Wester 1989). All manual removal disrupts the rhizomes, and the effect of this removal on the maintenance of the M. villosa population is unknown.

The use of flooding to aid in the control of alien plant species should also be explored. This should be implemented based on the results from Tasks #31 and #32.

There has been discussion in the past of chemical control of alien plant species. Chemical control is not recommended until it has been thoroughly tested and proven to have no adverse effect on M. villosa material grown ex situ, or on the natural ecosystem this plant occupies. Native snails and crustaceans may be particularly susceptible to the breakdown products of herbicides. In addition, the herbicides may cause an indirect effect by destroying the snails' and crustaceans' food supply, which is most likely the blue-green algae that is present in copious amounts during flooding. Little is known about the ecosystem, and chemicals that dissolve into the water column should be avoided to protect both the Marsilea villosa and the invertebrates.

34. Develop methods to control introduced mammals.

Improved methods must be developed to control introduced mammals, including mongoose and ungulates. Ungulate control is complicated by the fact that under some conditions, grazing appears to limit the invasion and spread of alien plants. Results of cattle removal from the Lualualei population indicate that limited grazing may control alien plants sufficiently to allow Marsilea villosa to persist. This balance should be carefully considered when designing ungulate control methods.

4. If populations no longer exist, develop and implement reintroduction plan for Ni`ihau and/or northwest Moloka`i.

If the populations searched for in Task #2 no longer exist, a plan should be developed to reintroduce Marsilea villosa into its historic range on Ni`ihau and/or Moloka`i in order to meet the downlisting objectives. Considerations in the plan would include site selection and preparation, determination of appropriate life stage for reintroduction (eg. spore, rhizome or propagated plant), methods for propagation,

if appropriate, etc.

41. Develop and implement reintroduction plan for Ni`ihau.

If appropriate, a plan to reintroduce Marsilea villosa into its historic range on Ni`ihau should be developed and implemented.

42. Develop and implement reintroduction plan in northwestern Moloka`i.

If appropriate, a plan to reintroduce Marsilea villosa into its historic range in northwestern Moloka`i should be developed and implemented.

5. Augment populations, as appropriate.

Because there are only five currently known populations of Marsilea villosa and these cover very small areas, removing the threats may not be enough to attain the recovery objective. Work may be needed to enhance growth and reproduction of the plants in these populations. Augmentation plans should be developed for extant and rediscovered and/or reintroduced populations. These plans should discuss appropriate methodologies, including selection of genetic material, criteria for monitoring and determining when augmentation is appropriate. Augmentation should be approached very cautiously and, if conducted, done with extreme care to avoid the possibility of introducing greenhouse pests, diseases or alien plants into a wild population.

51. Develop augmentation plan for O`ahu populations.

The populations of Marsilea villosa on O`ahu that need augmentation should be determined, and detailed augmentation plans developed.

52. Develop augmentation plan for Moloka`i populations.

The populations of Marsilea villosa on Moloka`i that need augmentation should be determined, and detailed augmentation plans developed.

53. Develop augmentation plan for Loe Lake, if appropriate.

A specific population augmentation plan, if appropriate, should be developed for the Loe Lake population on Ni`ihau, if determined to still exist (see Task #21).

54. Implement augmentation plans, as appropriate.

Augmentation plans for all extant populations of Marsilea villosa should be implemented as appropriate.

6. Study the ecology of the species.

The ecology of Marsilea villosa needs to be studied, including effects of moisture regime on the life cycle, soil composition, long-term demography, genetic variability, association with native and non-native invertebrates, and dependence upon and/or association with native and non-native birds.

61. Determine moisture and other requirements governing reproduction and maintenance.

In general, hydrology is known to be very important in maintaining *M. villosa* populations. However, the specific moisture and inundation requirements of various life stages remain to be determined. For example, it is important to know moisture levels at which young get established, sporocarps get initiated, and vegetative growth is initiated and ceases. It has been speculated that bare soil is optimal for establishment of young plants. These and other factors should be investigated.

62. Conduct soil analysis.

Soils should be analyzed for texture, Ph, mineral composition, organic content, and water retention capabilities. Samples should be taken from all known sites where the species occurs. Additional samples may also be useful in determining locations for reintroductions.

63. Study long-term demography.

A major unknown that should be addressed for *Marsilea villosa* is how often sexual reproduction is required for a population to remain healthy. Germination and survival rates are also unknown. To address these questions, permanent plots should be established in all five populations. Plots should include areas of dense *Marsilea villosa* and areas where *M. villosa* is more scattered.

In addition to annual surveys described in Task #13, each population should be visited following heavy rains to determine if flooding has occurred. If flooding takes place, populations should be closely monitored on a weekly basis to determine if sexual reproduction and young plant establishment occurs. The rate of establishment and survival of new plants after flooding and sexual reproduction occur is of particular importance in determining the minimum viable population size for the species.

64. Determine genetic variability.

The extensive vegetative growth of *Marsilea villosa* makes it difficult to determine the amount of genetic variability in each population and the number of individuals. A study of the genetic variability between and within populations is necessary to determine extent of clonal reproduction and the variation between populations. This information is an essential prerequisite to population augmentation and/or reestablishment efforts.

65. Determine minimum viable population size.

The minimum viable population size is currently unknown and will need to be determined following genetic and demographic studies in Tasks #63 and #64.

66. Determine association with native and non-native invertebrates.

The presence of crustaceans and succinid snails at Koko Head was noted above

(see Habitat Description section). Because little is known about the Marsilea villosa ecosystem and its association with native and non-native invertebrates, a study should be conducted to determine the extent, if any, of interdependence. It is important to the recovery of Marsilea villosa to understand and conserve all of the ecosystem components that support it.

67. Determine dependence upon and/or association with native and non-native birds.

It has been speculated that birds were responsible for establishing Marsilea on the Hawaiian islands. The extent to which native and non-native birds are necessary for dispersing M. villosa (Malone and Procter 1965) is deserving of study.

7. Verify recovery objectives.

Progress towards recovery should be reviewed on a five-year basis, and this plan updated and revised as needed.

71. Verify the number of individuals and populations needed to downlist and to delist.

The number of individuals and populations needed to downlist and to delist should be verified. Mathematical modeling (see Task #65) may be useful in accomplishing this task.

72. Revise the recovery objectives as needed.

Recovery objectives should be revised if new information suggests that the current objectives are inadequate.

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PART III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the Marsilea villosa recovery program, as set forth in this recovery plan. It is a guide for meeting the objectives discussed in Part II of this Plan. This schedule indicates task priority, task numbers, task descriptions, duration of tasks, the agencies responsible for committing funds, and lastly, estimated costs. The agencies responsible for committing funds are not, necessarily, the entities that will actually carry out the tasks. When more than one agency is listed as the responsible party, an asterisk is used to identify the lead entity.

The actions identified in the implementation schedule, when accomplished, should protect habitat for the species, stabilize the existing populations and increase the population sizes and numbers of Marsilea villosa. Monetary needs to reach this point are identified for all parties involved.

Priorities in Column 1 of the following implementation schedule are assigned as follows:

- Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
- Priority 2 - An action that must be taken to prevent a significant decline in species population / habitat quality, or some other significant negative impacts short of extinction.
- Priority 3 - All other actions necessary to provide for full recovery of the species.

Key to Acronyms Used in Implementation Schedule

ES	-	U.S. Fish and Wildlife Service, Ecological Services, Honolulu, Hawaii
DNLR	-	Hawaii Department of Land & Natural Resources
NBS	-	National Biological Survey
CCH	-	City and County of Honolulu
TNC	-	The Nature Conservancy
USN	-	U.S. Navy
WA	-	Waimea Arboretum
BE	-	Bishop Estate
AUSA	-	Alpha U.S.A. Inc.
MOR	-	Moloka'i Ranch
ROB	-	Robinson Family
TBD	-	To Be Determined
O	-	Ongoing
C	-	Continuous

Recovery Plan Implementation Schedule for Marsilea villosa

MARCH 1996

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000'S)						
						FY 1996	FY 1997	FY1998	FY 1999	FY 2000	FY 2001	FY 2002
O'ahu populations:												
1	111	Protect Koko Head	2	CCH	2	1	1					
				*TNC	6	3	3					
1	112	Protect Lualualei	2	*USN	2	1	1					
				ES	6	3	3					
				DLNR	2	1	1					
1	113	Protect Makapu'u	2	BE	2	1	1					
				*ES	6	3	3					
				DLNR	2	1	1					
1	1141	Monitor and control development affecting Koko Head	C	CCH	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				TNC	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				*DLNR	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				ES	18	1	1	1	1	1	1	1
1	1142	Control mongoose at Koko Head	C	CCH	10.5	2	0.5	0.5	0.5	0.5	0.5	0.5
				*TNC	10.5	2	0.5	0.5	0.5	0.5	0.5	0.5
1	1143	Control alien plant species at Koko Head	C	*TNC	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				CCH	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1	1144	Limit trampling and off-road vehicle use at Koko Head	O	*CCH	54	3	3	3	3	3	3	3
				TNC	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1	1145	Reduce risk of fire at Koko Head	C	*CCH	10	1	1	0.5	0.5	0.5	0.5	0.5
				TNC	10	1	1	0.5	0.5	0.5	0.5	0.5
1	1151	Develop Endangered Species Management Plan at Lualualei	2	ES	4	2	2					
				*USN	6	3	3					
				DLNR	4	2	2					
1	1152	Monitor and control development affecting Lualualei	C	*ES	18	1	1	1	1	1	1	1
				USN	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				DLNR	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1	1153	Control grazing and trampling by cattle at Lualualei	C	*USN	24	3	3	3	1	1	1	1
				ES	18	1	1	1	1	1	1	1
1	1154	Control mowing at Lualualei	C	*USN	8.5		0.5	0.5	0.5	0.5	0.5	0.5
				ES	8.5		0.5	0.5	0.5	0.5	0.5	0.5

Recovery Plan Implementation Schedule for Marsilea villosa

MARCH 1996

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000'S)						
						FY 1996	FY 1997	FY1998	FY 1999	FY 2000	FY 2001	FY 2002
1	1155	Control alien plant species at Lualualei	C	*USN	17		1	1	1	1	1	1
				ES	17		1	1	1	1	1	1
1	1156	Reduce risk of fire at Lualualei	C	*USN	10	1	1	0.5	0.5	0.5	0.5	0.5
				ES	10	1	1	0.5	0.5	0.5	0.5	0.5
1	1161	Monitor and control development affecting Makapu'u	C	*ES	18	1	1	1	1	1	1	1
				BE	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				DLNR	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1	1162	Control alien plants at Makapu'u	C	ES	17		1	1	1	1	1	1
				DLNR	17		1	1	1	1	1	1
				*BE	17		1	1	1	1	1	1
1	1163	Limit trampling and off-road vehicle use at Makapu'u	C	ES	10	1	1	0.5	0.5	0.5	0.5	0.5
				DLNR	10	1	1	0.5	0.5	0.5	0.5	0.5
				*BE	10	1	1	0.5	0.5	0.5	0.5	0.5
1	1164	Reduce risk of fire at Makapu'u	C	*BE	10	1	1	0.5	0.5	0.5	0.5	0.5
				DLNR	10	1	1	0.5	0.5	0.5	0.5	0.5
				ES	10	1	1	0.5	0.5	0.5	0.5	0.5
Moloka'i populations:												
1	121	Conduct additional surveys at Kamaka'ipo	2	AUSA	1	0.5	0.5					
				*ES	1	0.5	0.5					
				DLNR	1	0.5	0.5					
1	122	Protect Kamaka'ipo	2	AUSA	2		1	1				
				*ES	6		3	3				
				DLNR	2		1	1				
1	123	Protect Moki'o	2	MOR	2	1	1					
				*ES	6	3	3					
				DLNR	2	1	1					
1	1241	Monitor and control development affecting Kamaka'ipo	C	*ES	18	1	1	1	1	1	1	1
				AUSA	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				DLNR	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1	1242	Control grazing and trampling by deer at Kamaka'ipo	C	AUSA	42	10	10	3	3	3	1	1
				ES	42	10	10	3	3	3	1	1
				*DNLR	42	10	10	3	3	3	1	1

Recovery Plan Implementation Schedule for Marsilea villosa

MARCH 1996

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000'S)						
						FY 1996	FY 1997	FY1998	FY 1999	FY 2000	FY 2001	FY 2002
				ES	10	1	1	0.5	0.5	0.5	0.5	0.5
1	1251	Monitor and control development affecting Moki'o	C	*ES	18	1	1	1	1	1	1	1
				MOR	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				DLNR	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1	1252	Making one contiguous population at Moki'o	2	*ES	10	5	5					
				MOR	6	3	3					
				DLNR	6	3	3					
1	1253	Control grazing and trampling by deer and cattle at Moki'o	C	MOR	42	10	10	3	3	3	1	1
				ES	42	10	10	3	3	3	1	1
				*DLNR	42	10	10	3	3	3	1	1
1	1254	Control alien plant species at Moki'o	C	MOR	17		1	1	1	1	1	1
				ES	17		1	1	1	1	1	1
				*DLNR	17		1	1	1	1	1	1
1	1255	Reduce risk of fire at Moki'o	C	MOR	10	1	1	0.5	0.5	0.5	0.5	0.5
				*DLNR	10	1	1	0.5	0.5	0.5	0.5	0.5
				ES	10	1	1	0.5	0.5	0.5	0.5	0.5
1	13	Conduct annual monitoring	C	*ES	54	3	3	3	3	3	3	3
				DLNR	36	2	2	2	2	2	2	2
1	14	Provide information and education for nursery industry	C	*ES	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
				DLNR	9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1	15	Preserve genetic stock	C	*WA	10	1	1	0.5	0.5	0.5	0.5	0.5
				ES	10	1	1	0.5	0.5	0.5	0.5	0.5
				DLNR	10	1	1	0.5	0.5	0.5	0.5	0.5
				TNC	10	1	1	0.5	0.5	0.5	0.5	0.5
				USN	10	1	1	0.5	0.5	0.5	0.5	0.5
				BE	10	1	1	0.5	0.5	0.5	0.5	0.5
2	211	Survey site at Loe Lake	1	ES	1			1				
				*DLNR	1			1				
				ROB	1			1				
2	212	Ascertain if sporocarps present at Loe Lake	2	ES	2			1	1			
				*DLNR	2			1	1			
				ROB	2			1	1			

Recovery Plan Implementation Schedule for Marsilea villosa

MARCH 1996

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000'S)						
						FY 1996	FY 1997	FY1998	FY 1999	FY 2000	FY 2001	FY 2002
2	221	Protect population at Loe Lake	2	*ES	6					3	3	
				DLNR	2					1	1	
				ROB	2					1	1	
2	2221	Control grazing and trampling by introduced mammals at Loe Lake	C	ES	30							7
				*DLNR	30							7
				ROB	30							7
2	2222	Control alien plants at Loe Lake	C	ES	12							1
				*DLNR	12							1
				ROB	12							1
2	2223	Control risk of fire at Loe Lake	C	ES	7							1
				*DLNR	7							1
				ROB	7							1
2	223	Preserve genetic stock at Loe Lake	C	*WA	11							3
				ES	11							3
				ROB	11							3
2	231	Survey sites at Mo'omomi	1	ES	3							3
				*DLNR	3							3
				TNC	3							3
2	232	Survey site at 'Ilio	1	ES	3							3
				*DLNR	3							3
				MOR	3							3
2	233	Ascertain if sporocarps present northwestern Moloka'i	2	ES	6							3
				*DLNR	6							3
2	24	Preserve genetic stock from extant populations	1	ES	3							3
				DLNR	3							3
				*WA	3							3
2	251	Protect site at Mo'omomi	2	TNC	2							
				*ES	6							
				DLNR	2							
2	252	Protect site at 'Ilio	2	MOR	2							
				*ES	6							
				DLNR	2							

Recovery Plan Implementation Schedule for Marsilea villosa

MARCH 1996

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000'S)						
						FY 1996	FY 1997	FY1998	FY 1999	FY 2000	FY 2001	FY 2002
2	2531	Control grazing and trampling by cattle and/or deer at northwest Moloka'i	C	ES *DLNR	35 40							
2	2532	Control alien plants at northwest Moloka'i	C	ES *DLNR	8 16							
2	2533	Control risk of fire at northwest Moloka'i	C	ES *DLNR	5 10							
		Need 1 (Secure and stabilize current populations)			1505	147.5	158.5	74	64	66	54	118
2	31	Determine effects of changes in hydrology	5	ES *DLNR NBS	5 15 5		1 3 1	1 3 1	1 3 1	1 3 1	1 3 1	
2	32	Develop methods and procedures to control hydrology changes	5	ES *DLNR NBS	10 10 15						2 2 3	2 2 3
2	33	Develop methods to control alien plants	5	ES *DLNR NBS	15 30 15		3 6 3	3 6 3	3 6 3	3 6 3	3 6 3	
2	34	Develop methods to control introduced mammals	5	ES *DLNR NBS	15 30 15		3 6 3	3 6 3	3 6 3	3 6 3	3 6 3	
		Need 2 (Conduct Research on Limiting Factors)			180	0	29	29	29	29	36	7

Recovery Plan Implementation Schedule for Marsilea villosa

MARCH 1996

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000'S)						
						FY 1996	FY 1997	FY1998	FY 1999	FY 2000	FY 2001	FY 2002
2	41	Develop and implement reintroduction plan for Ni'ihau	5	*ES	23							
				DLNR	21							
				ROB	9							
2	42	Develop and implement reintro. plan for northwest Moloka'i	5	*ES	23							
				DLNR	21							
		Need 3 (Reintroduce in Former Range)			97	0	0	0	0	0	0	0
2	51	Develop augmentation plan for O'ahu populations	2	*ES	6				3	3		
				CCH	4				2	2		
				TNC	4				2	2		
				USN	4				2	2		
				BE	4				2	2		
2	52	Develop augmentation plan for Moloka'i populations	2	*ES	6				3	3		
				AUSA	4				2	2		
				MOR	4				2	2		
2	53	Develop augmentation plan for Loe Lake	2	*ES	6						3	3
				ROB	4						2	2
2	54	Implement augmentation plans as appropriate	C	*ES	26						2	2
				CCH	13						1	1
				TNC	13						1	1
				USN	13						1	1
				BE	13						1	1
				AUSA	13						1	1
				MOR	13						1	1
				ROB	13						1	1
		Need 4 (Augment Current Populations)			163	0	0	0	18	18	14	14

Recovery Plan Implementation Schedule for Marsilea villosa

MARCH 1996

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000'S)						
						FY 1996	FY 1997	FY1998	FY 1999	FY 2000	FY 2001	FY 2002
3	61	Study requirements for reproduction and maintenance	5	*NBS	15		3	3	3	3	3	
				DLNR	15		3	3	3	3	3	
				ES	15		3	3	3	3	3	
3	62	Conduct soil analysis	5	*NBS	15		3	3	3	3	3	
				DLNR	15		3	3	3	3	3	
				ES	15		3	3	3	3	3	
3	63	Study long term demography	10	*NBS	70		7	7	7	7	7	7
				DLNR	50		5	5	5	5	5	5
				ES	40		4	4	4	4	4	4
3	64	Determine genetic variability	5	*NBS	25		5	5	5	5	5	
				DLNR	25		5	5	5	5	5	
				ES	25		5	5	5	5	5	
3	65	Determine minimum viable population size	3	*NBS	9							3
				DLNR	9							3
				ES	9							3
3	66	Determine association with invertebrates	10	*NBS	30		3	3	3	3	3	3
				DLNR	30		3	3	3	3	3	3
				ES	30		3	3	3	3	3	3
3	67	Determine association with birds	10	*NBS	30		3	3	3	3	3	3
				DLNR	30		3	3	3	3	3	3
				ES	30		3	3	3	3	3	3
		Need 5 (Study Ecology of the Species)			532	0	67	67	67	67	67	43
3	71	Verify # individs. & pops. needed to reach downlisting and delisting	5	*ES	20							
				NBS	20							
				DLNR	20							
3	72	Revise recovery objectives as needed	2	*ES	3							
				FWS-RES	3							
				DLNR	3							
		Need 6 (Validate Recovery Objectives)			69	0	0	0	0	0	0	0
TOTAL COST					2546	147.5	254.5	170	178	180	171	182

APPENDIX A - LIST OF REVIEWERS

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